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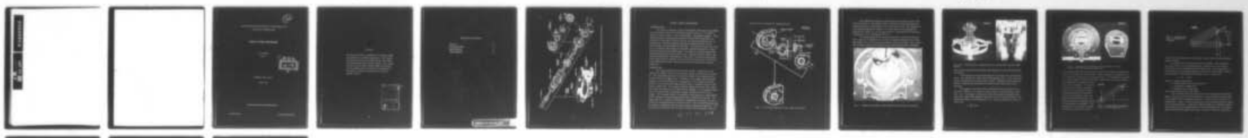

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GIMBAL CAGING MECHANISM

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LEXINGTON MASSACHUSETTS

Abstract

This note describes a mechanism for caging a single-axis gimbal for a satellite application. The caging mechanism consists of two pivoted links that clamp the gimbal shaft in the nominal position. The clamping load is produced by a double toggle mechanism. A nonreusable actuator releases the mechanism on command; a caging override permits unlimited manual release.

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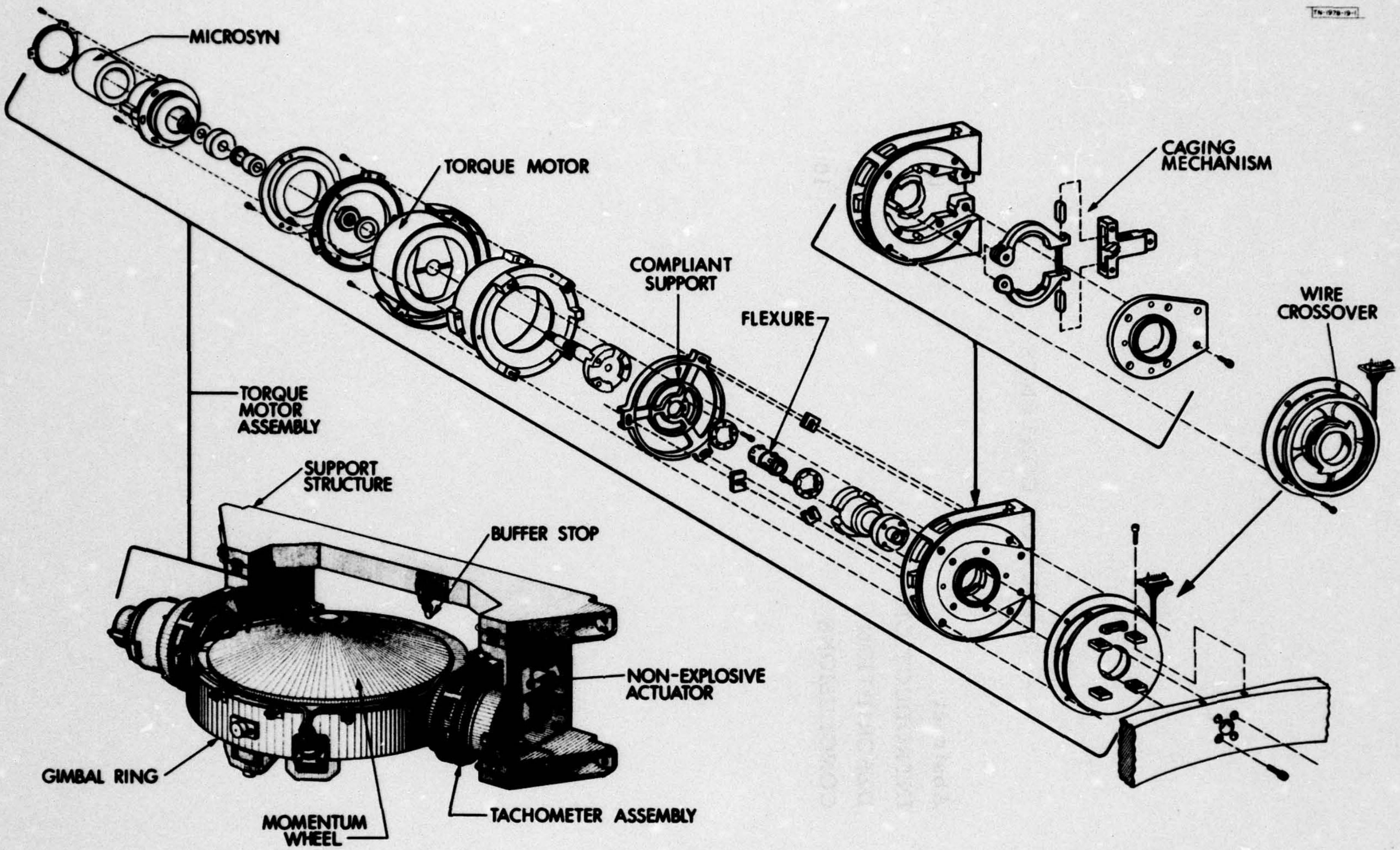

Fig. 1. One of two caging mechanisms for a 25-lb gimbal momentum wheel.

GIMBAL CAGING MECHANISM

INTRODUCTION

The caging mechanism is part of the gimbal momentum wheel (GMW) used for attitude control of the LES-8/9 satellites (Fig. 1). The GMW is used as a reaction wheel, control moment gyro, and nutation damper. In the damping mode it is desirable to minimize friction about the gimbal axis, otherwise a dead band will exist resulting in reduced pointing accuracy of the satellite. For this reason the gimbal was suspended with flexural pivots instead of conventional ball bearings. The low-load rating of the flexures necessitated some means of caging the gimbaled assembly to sustain the ground handling and launch loads. The caging mechanism supports the 25-pound gimbal assembly at both ends by clamping the gimbal shaft in the nominal position with a symmetrical radial load. A primary consideration in the design of the mechanism was to minimize displacement of the flexure in the caged position under load and also during the caging and uncaging sequences.

DESCRIPTION

The caging mechanism consists of a housing, caging links, pivot, toggle links, toggle yoke and cam assembly spring, and housing cover (Fig. 2). The caging links mount to the pivot pin located in the housing and are actuated by the two toggle links. Translation of the toggle yoke toward the gimbal axis permits rotation of the caging links by the spring to the open position. A cam within the toggle yoke provides a redundant means of opening the caging links. The torque driving the caging links open in the redundant mode is generated by the load from the actuator. The kinematic motion in the redundant mode is designed to lag the link motion induced by the spring. The redundant feature is necessary in this particular configuration of the mechanism because hinge pins are not used at the pivot points. The toggle links have cylindrical ends and the caging links and toggle yoke have cylindrical mating grooves for the pivot action. This configuration duplicates the function of hinge pins and provides a neater packaging arrangement. The spring also provides the force to seat the links of the mechanism in the un-

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caged position and during the caging sequence.

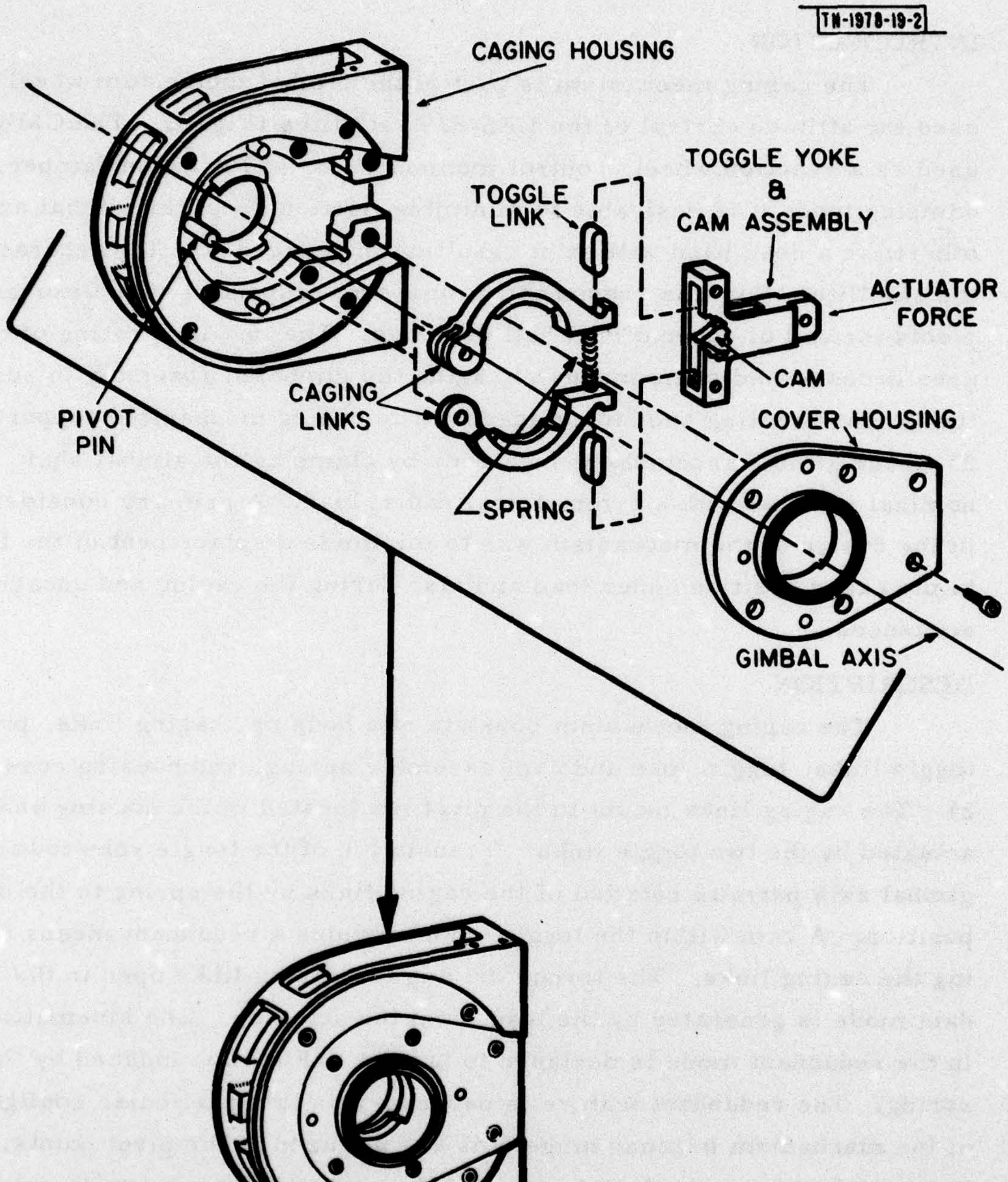


Fig. 2. Principal components of the caging mechanism.

The caging links support the gimbal shaft in the plane normal to the shaft axis (Fig. 3). The gimbal shaft is restrained axially by nesting the caging links into a conical groove in the shaft (Fig. 4a, b). The caging links are restrained axially by mating to a conical feature in the housing and housing cover (Fig. 5). In the caged position, the gimbal axis is kept from rotating by a set of abutting pins (Fig. 3).

The configuration of the caging housing was a result of its function with respect to the GMW as well as with the caging mechanism and a compact design was achieved by integrating the features as shown. As a result the structural aspect of the linkage was dictated from practical considera-

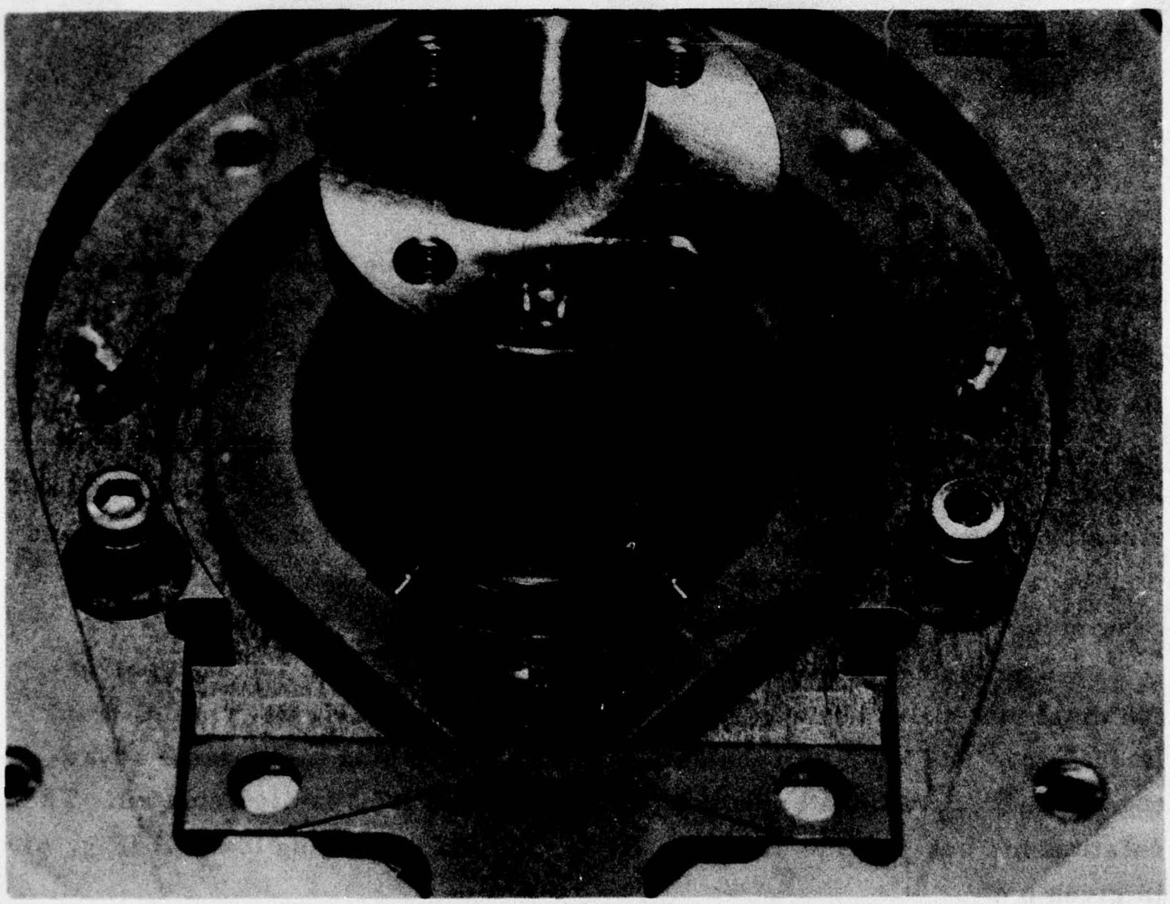
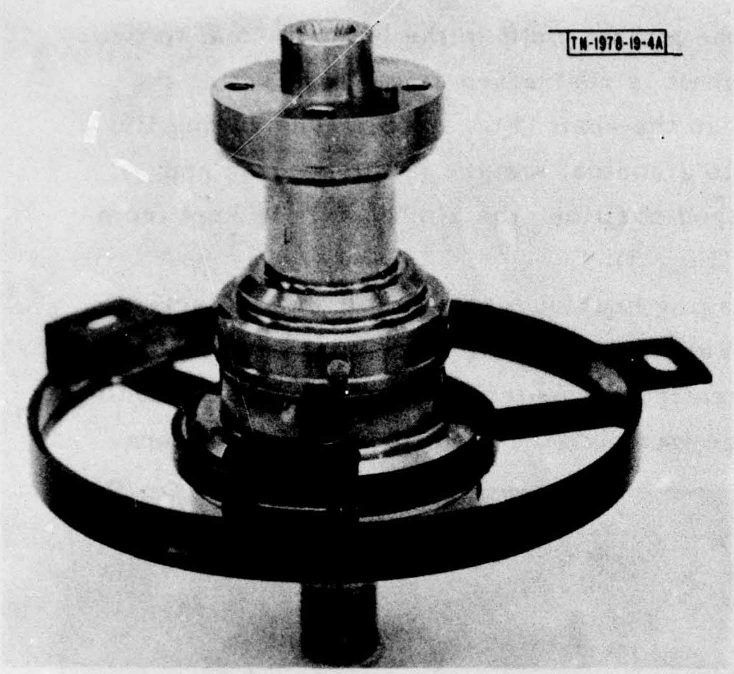


Fig. 3. Caging links support gimbal shaft in plane normal to shaft axis.



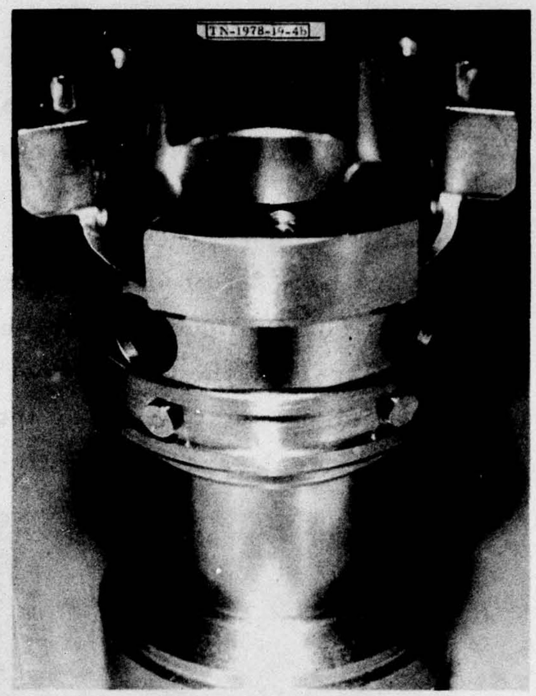


Fig. 4a, b. Conical groove in gimbal shaft for caging links restrains shaft axially.

tions and the stress analysis showed large margins of safety and small displacements.

The housings were made from 6061-T6 aluminum with a hard anodize finish. The linkage was made from 17-4PH stainless steel. A dry film lubricant was applied to the surfaces of the links. Alignment of the caging and flexure centerline was maintained by machining the caging link bore at assembly.

The toggle is one of the oldest mechanisms known and also one of the most versatile. It is used as a stone crusher, machinist clamp, trunk latch, etc. The toggle mechanism provides increasing mechanical advantage as the toggle links approach dead center and it is easily actuated. The relationship between the actuating force, F, and the caging load, P (Fig. 6) is given by:

$$P = \frac{F}{2} \mathrm{CTN}\, \theta$$

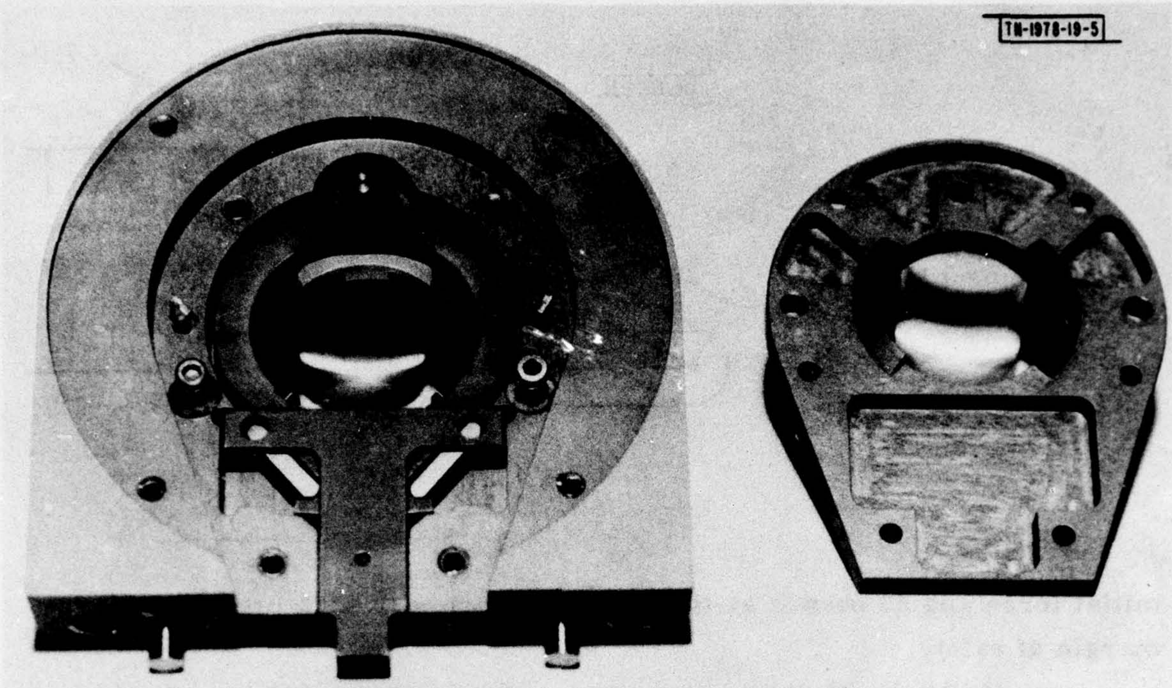


Fig. 5. Caging links restrained axially by mating to conical feature in the housing and housing cover.

In the caged position the angle θ was controlled to be slightly less than 1/2 degree on the open side of dead center, which resulted in a caging force, P, of 62 pounds for each pound of restraining force. The spring force provides an opening torque of 10 inch-pounds that is sufficient to overcome friction and caging strain so that the mechanism is self-actuating. The angle θ, coefficient of friction, and spring torque may be controlled so that in the caged position the mechanism may be self-actuating, motion impending or nonself-actuating. The choice depends on the application and the initiating force available. The actuator used to release the caging mechanism provided a 55-pound

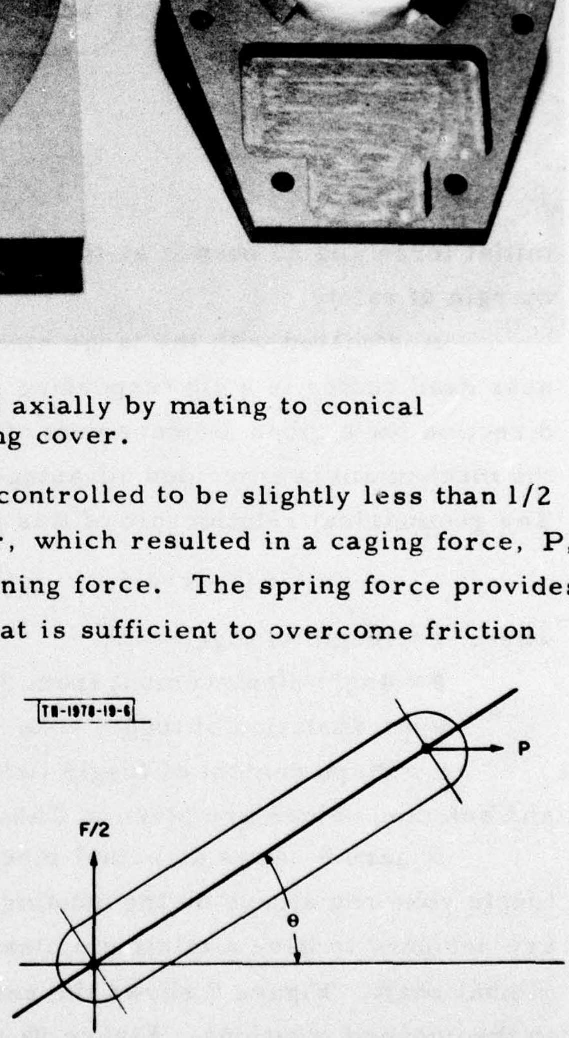


Fig. 6. Relationship of actuating force, F, and caging load, P.

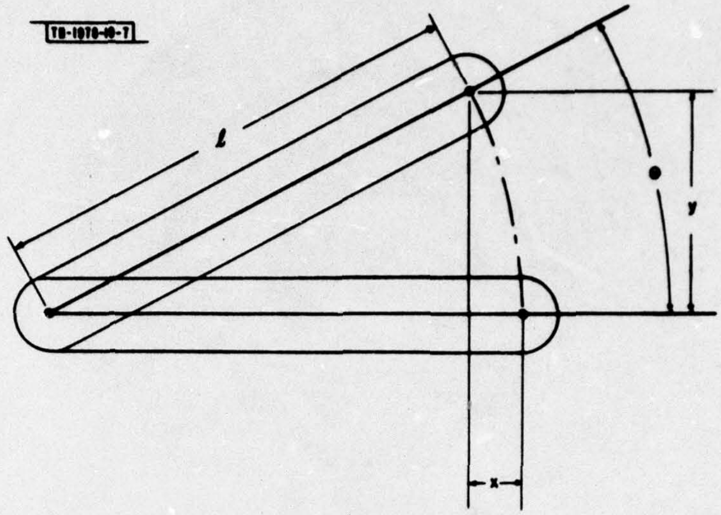


Fig. 7. Caging mechanism is insensitive to vibration.

initial force and 20 pounds at the end of the stroke, which provided a large margin of safety.

Associated with the large mechanical advantage of the mechanism near dead center is a corresponding small displacement in the uncaging direction for a given displacement of the toggle yoke. The insensitivity of the mechanism is a decided advantage in the event of motion under vibration. The geometrical relationship of this feature (Fig. 7) is given by:

$$x = \ell(1 - \cos\theta)$$

where ℓ = length of toggle link

θ = angle displacement from dead center

y = translation of toggle yoke

x = displacement of toggle link

and selected values are given in Table 1.

Figure 8 shows an actual mechanism in the uncaged position with the toggle yoke registered on the housing stop. In this position the caging links are designed to have a minimum clearance of 0.020 inch with respect to the gimbal shaft. Figure 9 shows the sequence of the mechanism from the caged to the uncaged positions. Figure 9a shows the toggle yoke registered against the housing stop in the caged position and the antirotation pins in the caging links and shaft butted against each other. Figure 9b shows the mechanism

TABLE I

TOGGLE LINK DISPLACEMENT (x) VS. ANGLE θ

θ (degree)	x (inch)	y (inch)	
0	0	0	
0.6	32×10^{-6}	0.006	caged position
1	86×10^{-6}	0.010	
2	344×10^{-6}	0.020	
3	776×10^{-6}	0.030	
4	1380×10^{-6}	0.040	
5	2150×10^{-6}	0.050	
52	0.148	0.448	uncaged position

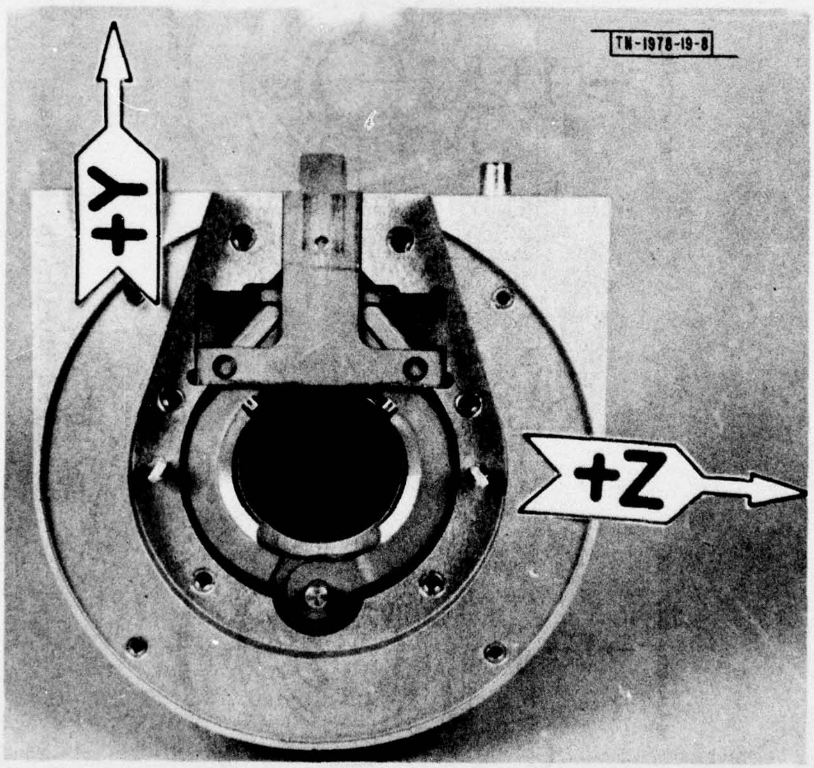


Fig. 8. Caging links in uncaged position.

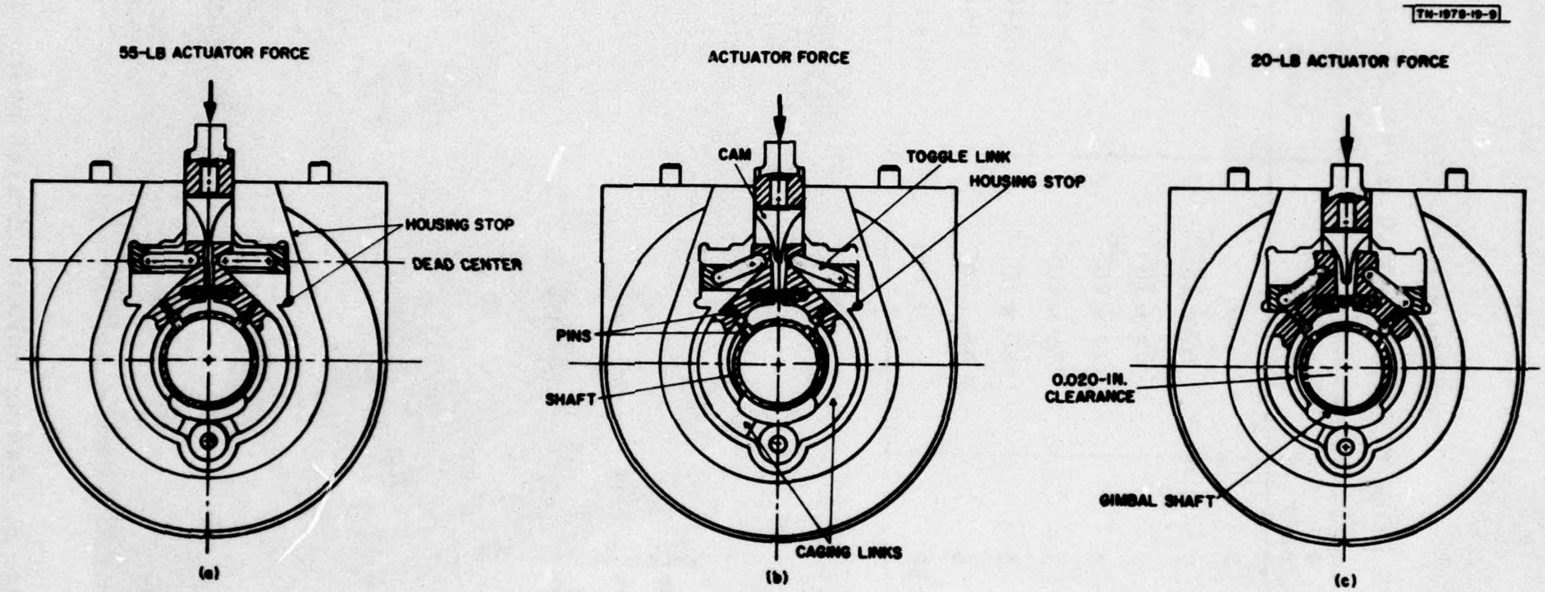


Fig. 9. Caging mechanism depicted moving from the (a) caged, to the (b) halfway, to the (c) uncaged position.

in the partially open position. The toggle yoke has translated towards the center of the shaft, the toggle links have rotated and permitted the caging links to rotate free of the shaft. Note the position of the cam relative to the caging links. Figure 9c shows the mechanism in the uncaged position with the toggle yoke registered against the housing stop. The caging links and toggle links are rotated to the full open position and the cam has moved deeper into the caging links. The smooth action of the mechanism and the close tolerance control of the assembly permitted the gimbal to be caged and uncaged without overloading the flexural pivot.

The mechanism was designed to support a 25-pound gimbal weight based on an equivalent static loading of 5g axial and 8g transverse, acting simultaneously, relative to the gimbal axis. The GMW was subjected to a random vibration test in three directions to the spectrum shown in Fig. 10 and to a shock spectrum in six directions (Fig. 11). Post-test calibration of the GMW verified the design concept of the caging mechanism. The flight units performed flawlessly on both the LES-8/9 satellites that were launched on March 14, 1976.

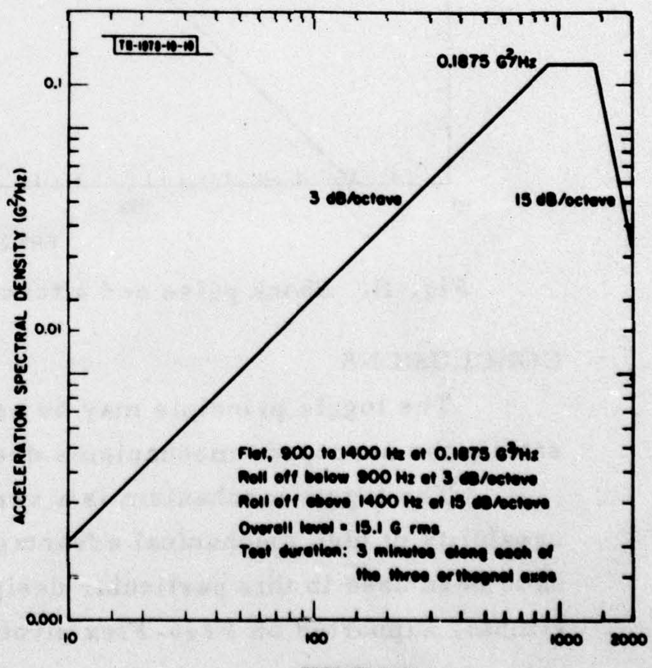


Fig. 10. Random vibration qualification test.

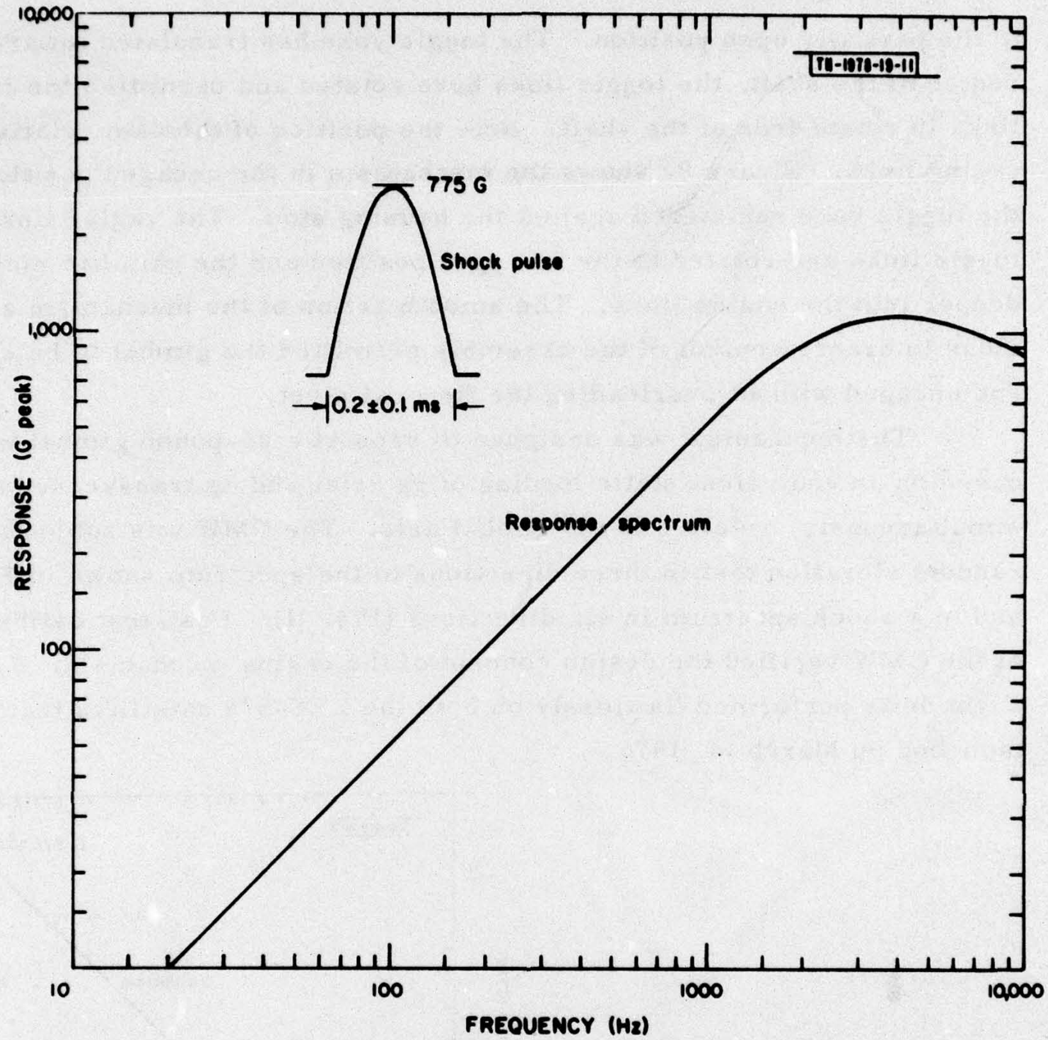


Fig. 11. Shock pulse and alternative shock response spectrum.

CONCLUSIONS

The toggle principle may be used in a variety of configurations to satisfy the aerospace mechanisms designer's requirements.

The toggle mechanism is a versatile, reliable mechanism with the capability of high mechanical advantage with low-input load. These features have been used in this particular design to successfully cage a 25-pound gimbal, supported on Free-Flex pivots, for a satellite application.

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